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FINAL REPORT

"Interferometric Test/Alignment of Water Window Imaging X-Ray Microscopes"

Prepared for:

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1.0 Introduction

This report details the tasks performed by the Center for Applied Optics (CAO) in support of the Normal Incidence, Multilayer X-ray Optics program at the Marshall Space Flight Center (MSFC). This work was carried out between November, 1993 and May, 1995.

This effort was concerned primarily with optical systems research as is detailed in Tasks 3.2 and 3.3 of contract NAS8-38609. In particular, work was to be conducted on the interferometric testing, optical alignment, and focusing of the Scharzschild X-ray Microscope developed at MSFC.

The effort was to be comprised of two primary tasks. First, interferometric testing was to be carried out on four new X-ray microscopes in order to evaluate their imaging capabilities and optical alignment. The tests were to be accomplished at MSFC using the CAO's Zygo interferometer. In the second task, experiments were to be conducted to help determine how to extract the highest performance from the photographic films used in the microscopes. The best focal position and the resulting spatial resolution of one 20X and one 30X X-ray microscope were then to be photographically determined. Again, most of these experiments were to be conducted on-site at MSFC.

2.0 Interferometric Testing

The University's Zygo PTI Fizeau-type interferometer (operating at the HeNe laser wavelength of 6328 Å) was set up in the X-ray optics lab in the Space Science Laboratory building (4481). The interferometer was hooked up to an MSFC computer with a frame grabber running the MicroFringe analysis program. Reference flats, optical mounts, tools, and micrometers were also supplied by the CAO for this testing. The set-up was checked using one of the $\lambda/20$ reference flats. After resolution of some initial problems with the PC, the test set-up was found to be accurate and repeatable.

At this point, the microscope optics were still in the process of being fabricated by another contractor for MSFC. Thus, there were no X-ray microscopes available for testing. With the test equipment set up and ready for use, it was decided to temporarily divert the effort to the alignment and focusing of the Multi-

Spectral Solar Telescope Array (MSSTA) II telescopes which were due to launch in the fall of 1994.

The interferometric procedure for aligning and focusing the Ritchey-Cretien and Cassegrain telescopes had been developed by the CAO prior to the first MSSTA flight in May of 1991. The design distance from the back of the Camera Mounting Flange (CMF) to the film plane was 3.453". However, due to slight variations in the as-mounted mirror positions as well as mirror shape, the true position of best-focus had to be determined for each of the nine two-mirror telescopes to be flown. Each telescope employed normal incidence, multi-layer optics to selectively image various solar emission lines between 150 Å and 1550 Å.

The telescopes were analyzed in a double-pass mode. In other words, the 4" diameter interferometer beam was projected into each telescope and a reference flat was placed near the focus to retro-reflect the beam back through the telescope and into the interferometer. An interferogram was taken and the wavefront quality measured as a function of position of the reference flat. When the best wavefront quality was observed, the distance from the back of the CMF to the flat was measured as the position of best focus. Using this method, the position of best-focus could be determined to within 0.001 inch. The 150, 173, 193, 304, & 335 Å Ritchey-Cretien telescopes and the 173 & 211 Å Cassegrain telescopes were all focused using this method. The exact positions of best focus were documented in the official NASA lab notebook for the MSSTA II project.

The 1550 Å telescope's mirrors were not reflective enough at 6328 Å for interferometric testing. Thus, this telescope was focused using a classic knife-edge test. A knife-edge was translated across the focused spot and the pattern of light observed as a function of knife-edge position. Best focus was achieved when the spot dimmed quickly and evenly across its diameter as the knife-edge was introduced. The 1216 Å Ritchey-Cretien was not available prior to delivery of the MSSTA to White Sands, NM for launch.

The MSSTA II payload was launched successfully on November 3, 1994 and produced sub-arc second images of the sun at several wavelengths. Further details of the MSSTA II alignment and focusing can be found in Ref. 1.

At the time of the MSSTA II launch, the microscope optics had still not been received. Thus, a 6-month no-cost extension to the contract was requested and

received. However, by the end of the extension, the microscope optics had still not arrived. This time a 3-month extension was requested and granted. Nevertheless, the microscope optics had not arrived at MSFC by the end of this extension. Thus, it was not possible to complete any interferometric or photographic tests on the microscopes.

3.0 Conclusion

The two-mirror telescopes of the MSSTA II payload were successfully aligned and focused during this effort. The payload accomplished sub-arc second images of the sun in the X-ray/EUV waveband. The techniques and experience developed under this effort should prove extremely useful in future X-ray optics efforts at MSFC.

References

- 1 D. Gore, J. Hadaway, R. Hoover, A. Walker, & C. Kankelborg, "Optical Focusing and Alignment of the Multi-Spectral Solar Telescope Array II Payload," *SPIE Proc.*, 1995.